

Appendix C - Water Quality Data



Table C-1. Summary of Bottom Sediment Analysis, Arrowrock Reservoir, 1991.									
Site Code*	AR-1	AR-2	AR-3	AR-4	AR-5	AR-6	AR-7	Western United States†	
Analysis Date	07/19	07/19	07/19	12/20	12/20	12/20	12/20	Mean	Observed Range
Aluminum (%-S)	7.3	7.4	7.9	7.8	7.8	8	6.9	7.4	0.5 - >10
Arsenic (ppm)‡	10	7.5	2.3	12	12	74	76	7.0	<0.10 - 97
Barium (ppm)	980	900	1100	930	1000	950	1200	670	70 - 5000
Beryllium (ppm)	3	4	3	3	3	4	2	0.97	<1 - 15
Bismuth (ppm)	<10	<10	<10	<10	<10	<10	<10		
Cadmium (ppm)	<2	<2	<2	<2	<2	<2	<2		
Calcium (%-S)	1	1	1	1.2	1	1	0.67	3.3	0.06 - 32
Cerium (ppm)	64	71	96	72	72	77	27	75	<150 - 300
Chromium (ppm)	18	22	14	26	19	25	3	56	3 - 2000
Cobalt (ppm)	5	5	4	6	6	7	3	9.0	<3 - 50
Copper (ppm)	7	10	5	13	9	13	2	27	2 - 300
Europium (ppm)	<2	<2	<2	<2	<2	<2	<2		
Gallium (ppm)	23	23	21	23	23	24	18	19	<5 - 70
Gold (ppm)	<8	<8	<8	<8	<8	<8	<8		
Holmium (ppm)	<4	<4	<4	<4	<4	<4	<4		
Iron (%-S)	1.7	1.9	1.4	2.2	1.9	2.4	0.91	2.6	0.01 - >10
Lanthanum (ppm)	41	44	57	43	43	45	17	37	<30 - 200
Lead (ppm)	24	27	23	31	25	31	14	20	<10 - 700
Lithium (ppm)	33	39	25	45	40	48	32	25	5 - 130
Magnesium (%-S)	0.37	0.44	0.3	0.55	0.46	0.55	0.23	1.0	0.03 - >10
Manganese (ppm)	460	420	370	450	410	560	160	480	30 - 5000
Mercury (ppm)	0.14	0.22	0.04	0.24	0.33	0.36	0.11	0.065	<0.01 - 4.6
M o l y b d e n u m (ppm)	<2	<2	<2	<2	<2	<2	<2		
Neodymium (ppm)	31	34	41	33	32	35	11	43	<70 - 300
Nickel (ppm)	6	8	4	10	7	9	<2	19	<5 - 700
Niobium (ppm)	24	24	33	28	31	30	12	10	<10 - 100
Phosphorus (%-S)	0.1	0.09	0.05	0.08	0.07	0.09	0.02		
Potassium (%-S)	2.5	2.4	3	2.4	2.7	2.5	2.8	None	0.19 - 6.3
Scandium (ppm)	4	5	3	6	5	6	2	9.6	<5 - 50
Selenium (ppm)	0.1	<0.1	<0.1	0.2	0.2	0.1	<0.1	0.34	<0.10 - 4.3
Silver (ppm)	<2	<2	<2	<2	2	3	2		
Sodium (%-S)	2.4	2.2	3.2	2.2	2.4	2.1	2.3	1.2	0.05 - 10

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Analysis Date	07/19	07/19	07/19	12/20	12/20	12/20	12/20	Mean	Observed Range
Strontium (ppm)	360	330	380	340	350	320	390	270	10 - 3000
Tantalum (ppm)	<40	<40	<40	<40	<40	<40	<40		
Thorium (ppm)	14	13	21	16	19	19	6	9.8	2.4 - 31
Tin (ppm)	<5	<5	<5	<5	<5	<5	<5	1.2	0.1 - 7.4
Titanium (%-S)	0.16	0.2	0.19	0.23	0.22	0.24	0.09	0.26	0.05 - 2.0
Uranium (ppm)	<100	<100	<100	<100	<100	<100	<100	2.7	0.68 - 7.9
Vanadium (ppm)	23	28	21	36	29	37	13	88	7 - 500
Ytterbium (ppm)	1	2	2	2	2	2	<1	3.0	<1 - 20
Yttrium (ppm)	18	22	18	23	19	23	4	25	10 - 150
Zinc (ppm)	77	100	54	110	88	110	41	65	10 - 2100

*AR-1: Depositional area above the May 31, 1991 reservoir water surface elevation (3071.71) with predominantly silt bottom sediments. This is a likely deposition point for sediment released from Kirby Dam when Arrowrock is near full pool.

AR-2: Similar to AR-1 but about 1 mile downstream.

AR-3: Slack water area where predominantly sand bedload was dropping out on May 31, 1991.

AR-4: Arrowrock bottom sediment 115 49' 31" 43 37' 0"

AR-5: Arrowrock bottom sediment 115 49' 32" 43 36' 34"

AR-6: Arrowrock bottom sediment 115 49' 47" 43 36' 28"

AR-7: Arrowrock bottom sediment 115 38' 29" 43 42' 26"

†U.S. Department of Interior, U.S. Geological Survey. 1984. *Element Concentrations in Soils and Other Surficial Materials of the Conterminous United States*.

‡parts per million

Table C-2. Average October through February Surface Water Quality, 500 feet upstream of Arrowrock Dam

Parameter	Mean	Maximum	Minimum	^{1/} Standard		
				Drinking Water	Irrigation	Cold Water Biota
Temperature (°C)	8.28	16.4	2.2			^{2/} 12°C June - August (daily average) 9°C Sept - Oct (daily average)
Dissolved Oxygen (mg/L)	9.87	12.4	5.4			6.0 mg/L In lakes and reservoirs this standards does not apply to: (1) The bottom 20% of water depth where depths are 35 meters or less. (2) The bottom 7 meters of water depth where depths are greater than 35 feet. (3) Those waters of the hypolimnion in stratified lakes and reservoirs.
pH	7.11	7.88	6.64	5.0 - 9.0	4.5 - 9.0	6.50 - 9.50
Conductivity (µmho/cm)	73	77	71		Crop dependent	
Turbidity (NTU)	1.6	2	<1			Below any applicable mixing zone, shall not exceed background turbidity by more than 50 NTU instantaneously or more than 25 NTU for more than 10 days.
Secchi (meters)	3.4	5.5	2.2			
Ortho Phosphorus as P (mg/L)	0.003	0.006	<0.003			
Nitrate + nitrite as N (mg/L)	0.046	0.11	<0.01	Nitrate - 10.0 Nitrite - 1.0		
Total ammonia as N (mg/L)	0.023	0.01	<0.01	0.05 mg/L		pH and Temperature Dependent

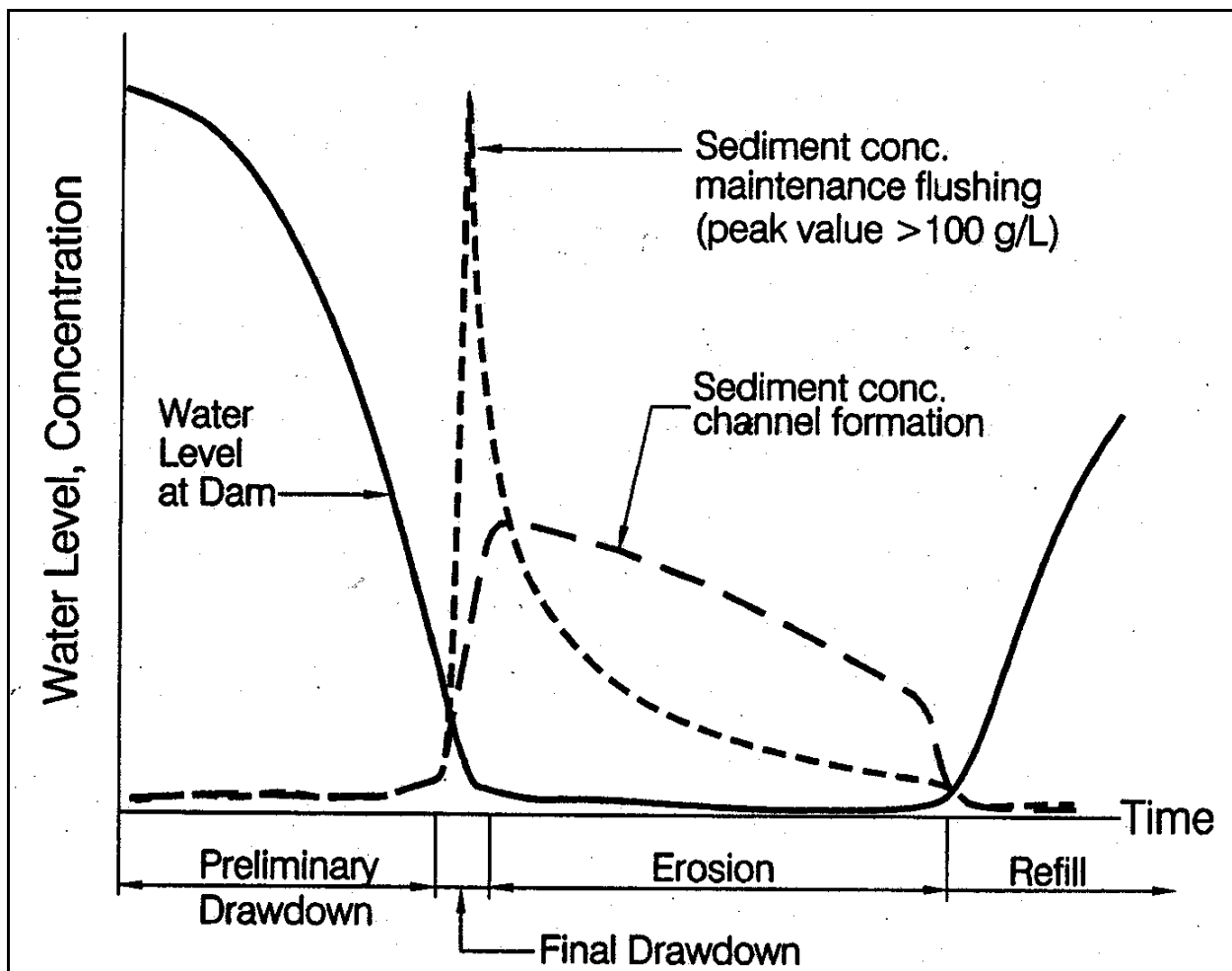
^{1/} Standards compiled from EPA *Water Quality Criteria, 1972* (Blue Book) and the Idaho Department Environmental Quality, *Water Quality Standards and Wastewater Treatment Requirements*.

^{2/} Bull Trout Temperature Criteria: Limited August and September reservoir data (instantaneous) suggests some exceedances of the bull trout temperature standard throughout the water column.

Figure C-1

Morris, G. L., and Fan, J. (1998). *Reservoir Sedimentation Handbook: Design and Management of Dams, Reservoirs, and Watersheds for Sustainable Use*. McGraw-Hill, New York.

Hydraulic and sediment characteristics for channel formation and channel maintenance flushing events at constant discharge (Morris and Fan, 1998.)



December 1984 Black Canyon Experimental Sluicing Operations

The experimental sluicing operation carried out in December 1984 at Black Canyon Dam, demonstrated the effect of reservoir inflow, outflow, and stage on the sediment concentrations moving past the dam. Figure 2 shows a plot of reservoir elevation versus grab sample concentration versus time. Figure 3 shows a plot of the reservoir inflow, outflow and grab sample concentrations versus time.

These plots show that higher concentrations up to 7,600 mg/L can occur at low reservoir levels, but at reservoir levels above elevation 2450 (40 acre-feet) concentrations drop off to less than 100 mg/L for all flows recorded. It appears also from this data that increased inflow does not necessarily increase the outflow concentrations. During the period December 8-10, the inflow increased from 1,200 to 2,150 cfs at the same time outflow sediment concentrations decreased from 768 to 366 mg/L. Since the inflow during the period exceeded outlet capacity, the reservoir elevation increased from elevation 2429.0 (0.50 acre-feet) to 2435.4 (2.0 acre-feet), which is the probable cause of decreased outflow concentrations.

Figure 4 shows the relationship of measured concentration of total suspended solids versus percent reservoir storage at the time of measurement and an estimated best fit curve to approximate that relationship. The regression coefficient suggests that a number of variables other than reservoir elevation influences total suspended solids in releases during sluicing operations.

For the 26 day period during the sluicing experiment from December 1 to December 27, 1984, the total volume of sediment sluiced from Black Canyon Reservoir is estimated to be 89 acre-feet, and the flow bypassed, 65,500 acre-feet. The volume of sediment sluiced during the experiment represents about 30 percent of the estimated annual sediment deposited, 292 acre-feet, in Black Canyon Reservoir.

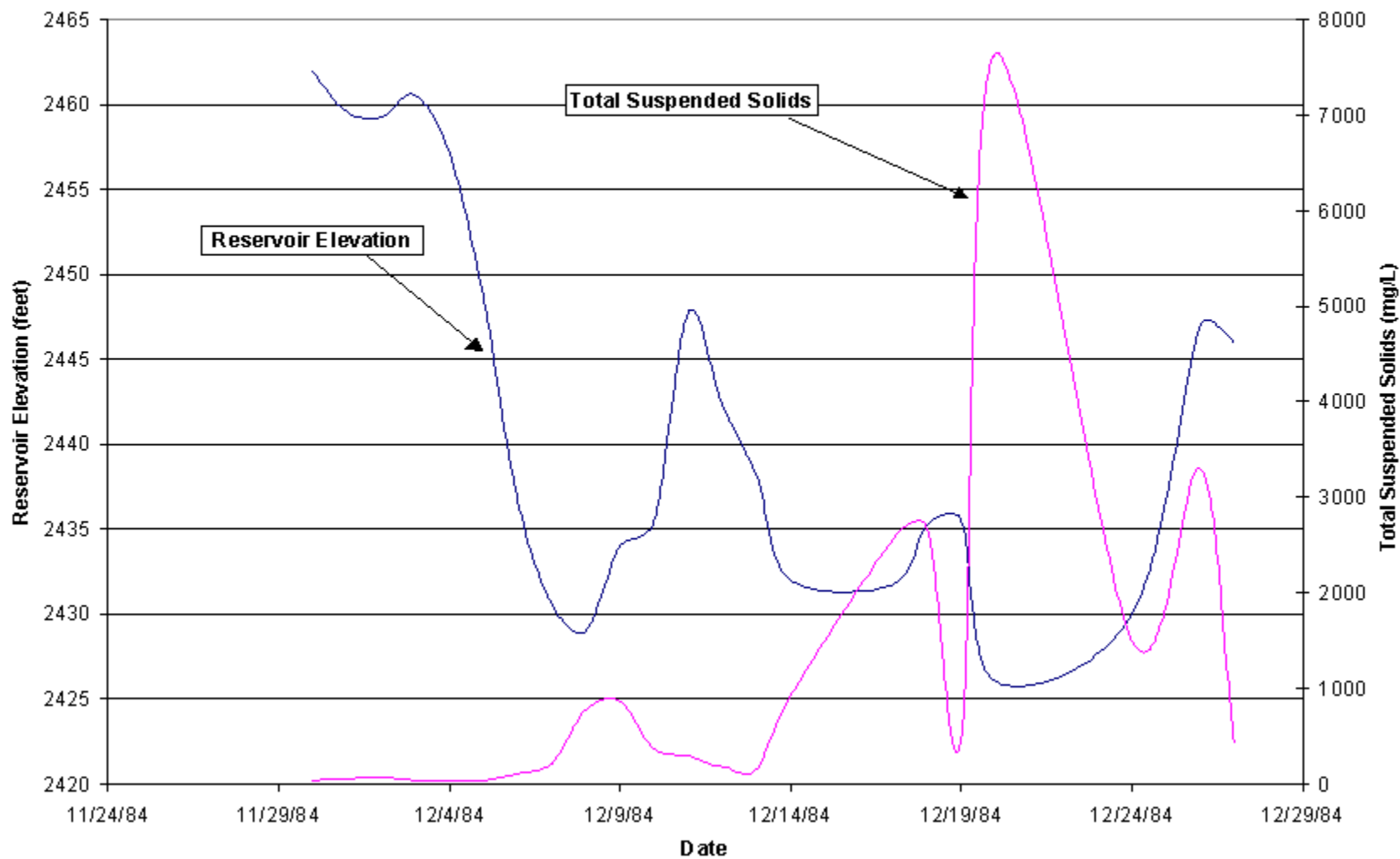
1994 Drawdown of American Falls Reservoir

The 1994 drawdown of American Falls Reservoir illustrates the patterns of total suspended solids and turbidity concentrations in relation to reservoir elevation using near bottom release, no sluice gates. The drawdown of American Falls Reservoir to elevation 4302.75, 18 feet above the outlets, resulted in a residual pool of 17,500 acre-feet, approximately 1 percent of the total reservoir storage. The outlet works consists of nine 7 foot 2 inch by 7 foot 2 inch conduits located at elevation 4285. Turbidity and total suspended solids concentrations began to increase quickly during the drawdown when the elevation of the reservoir reached 4306 (49,300 acre-feet). Turbidity and total suspended solids concentrations continued to increase even though the discharge from the dam decreased (figure 5), indicating that downstream concentrations of turbidity and total suspended solids are more likely related to the reservoir elevation rather than the discharge (figure 6). Had the reservoir been drained to the elevation of the outlet works, 4285, turbidity and total suspended sediment concentrations in the discharge would likely have been more related to the magnitude of the discharge and dam operations (somewhat like Black Canyon 1984).

Relationship between total suspended solids and percent reservoir storage at American Falls is somewhat weaker than was noted with the Black Canyon drawdown using sluice gates (figures 4 and 7). The relationship between total suspended solids concentration in dam releases and reservoir elevation suggests that total suspended solids concentrations in dam releases during extreme drawdowns are likely to be lower without sluice gate operation.

Figure 2

Total Suspended Solids Concentration in Black Canyon Reservoir Release During the 1984 Drawdown



**Figure 3 Daily Average Flow and Total Suspended Solids Concentration
Black Canyon Reservoir Release During the 1984 Drawdown**

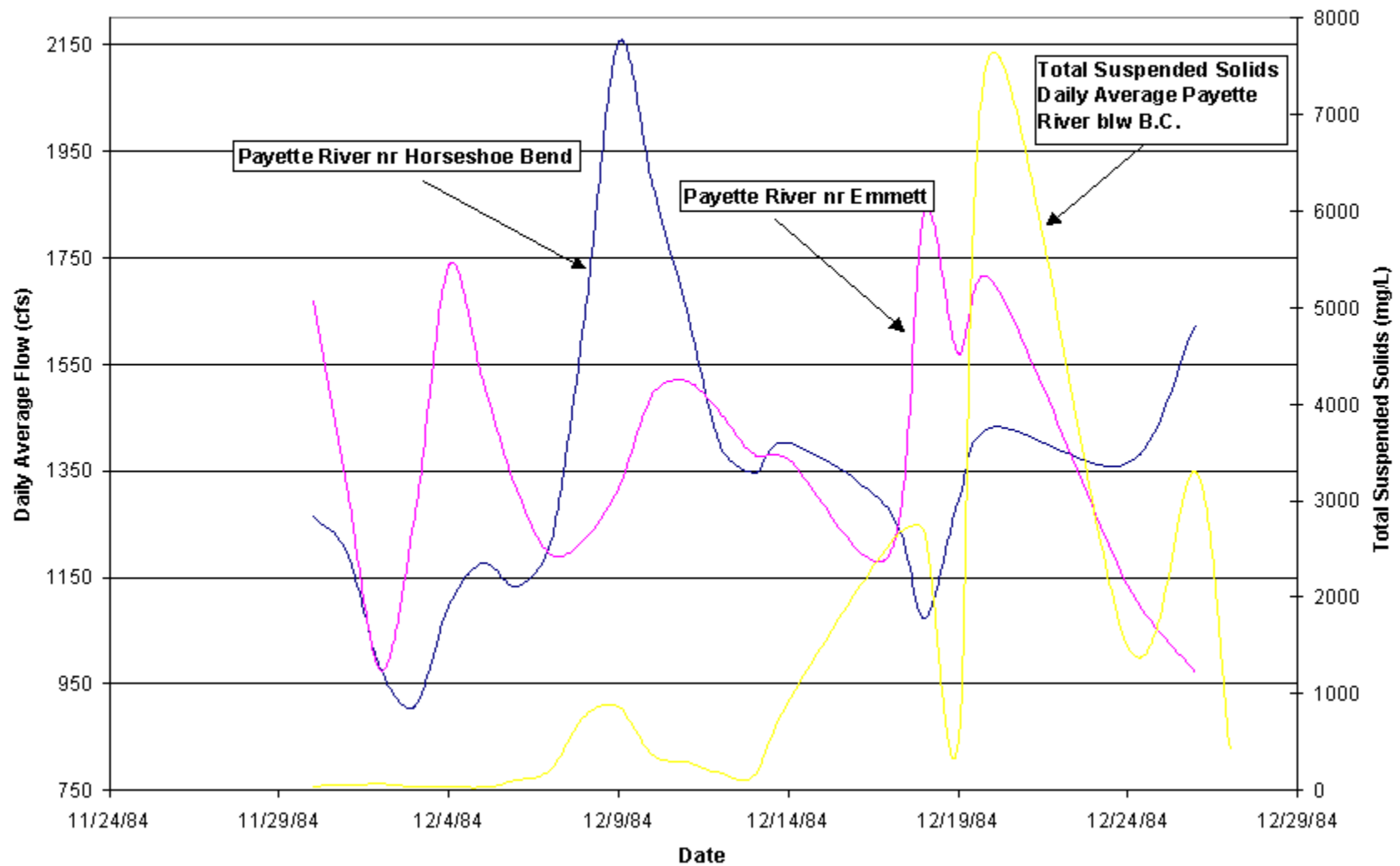


Figure 4

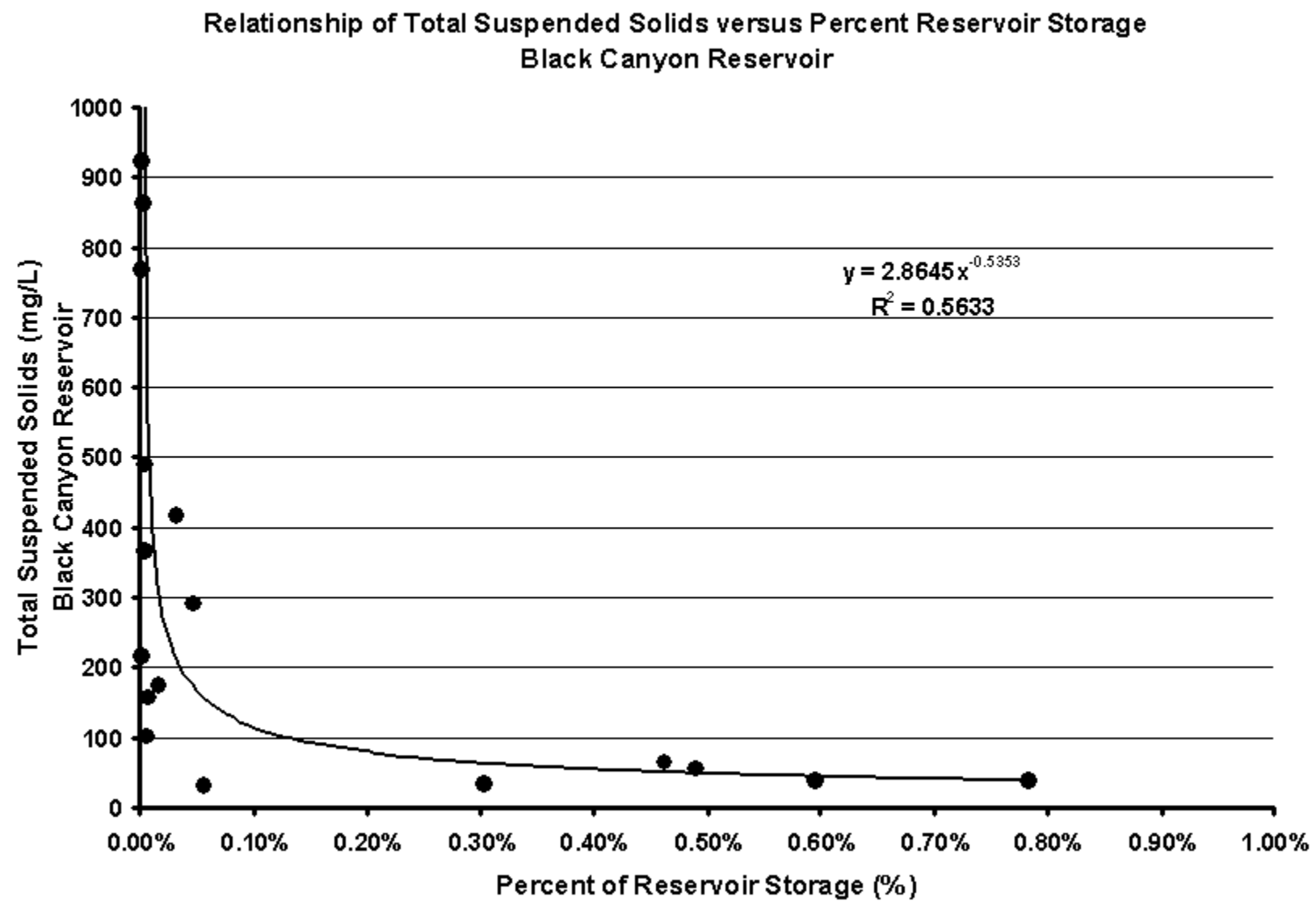


Figure 5

Daily Average Flow, Turbidity, and Total Suspended Solids Concentrations American Falls Release During 1994 Drawdown

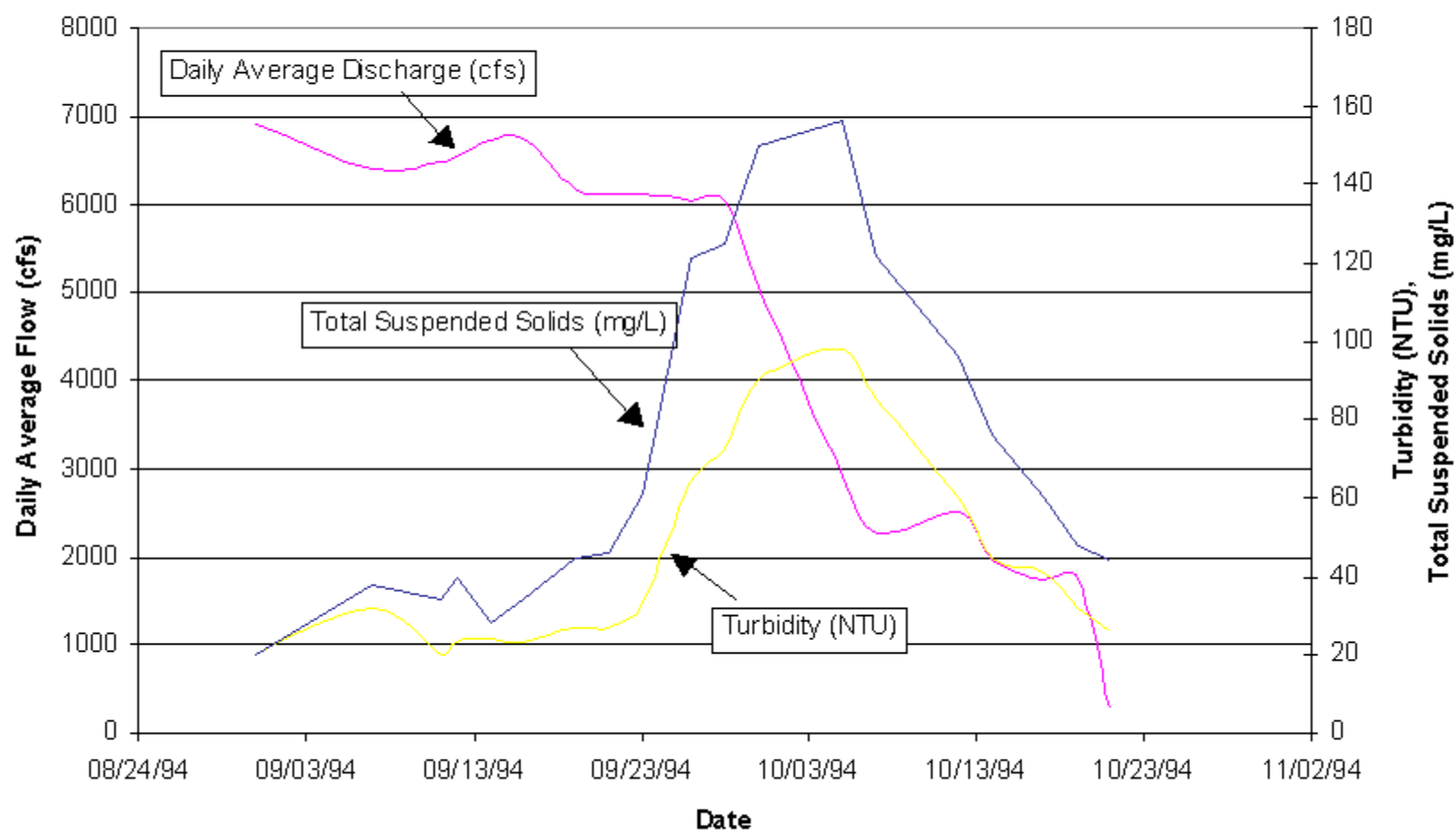


Figure 6

**Reservoir Elevation, Turbidity, and Total Suspended Solids Concentrations
American Falls Reservoir During the 1994 Drawdown**

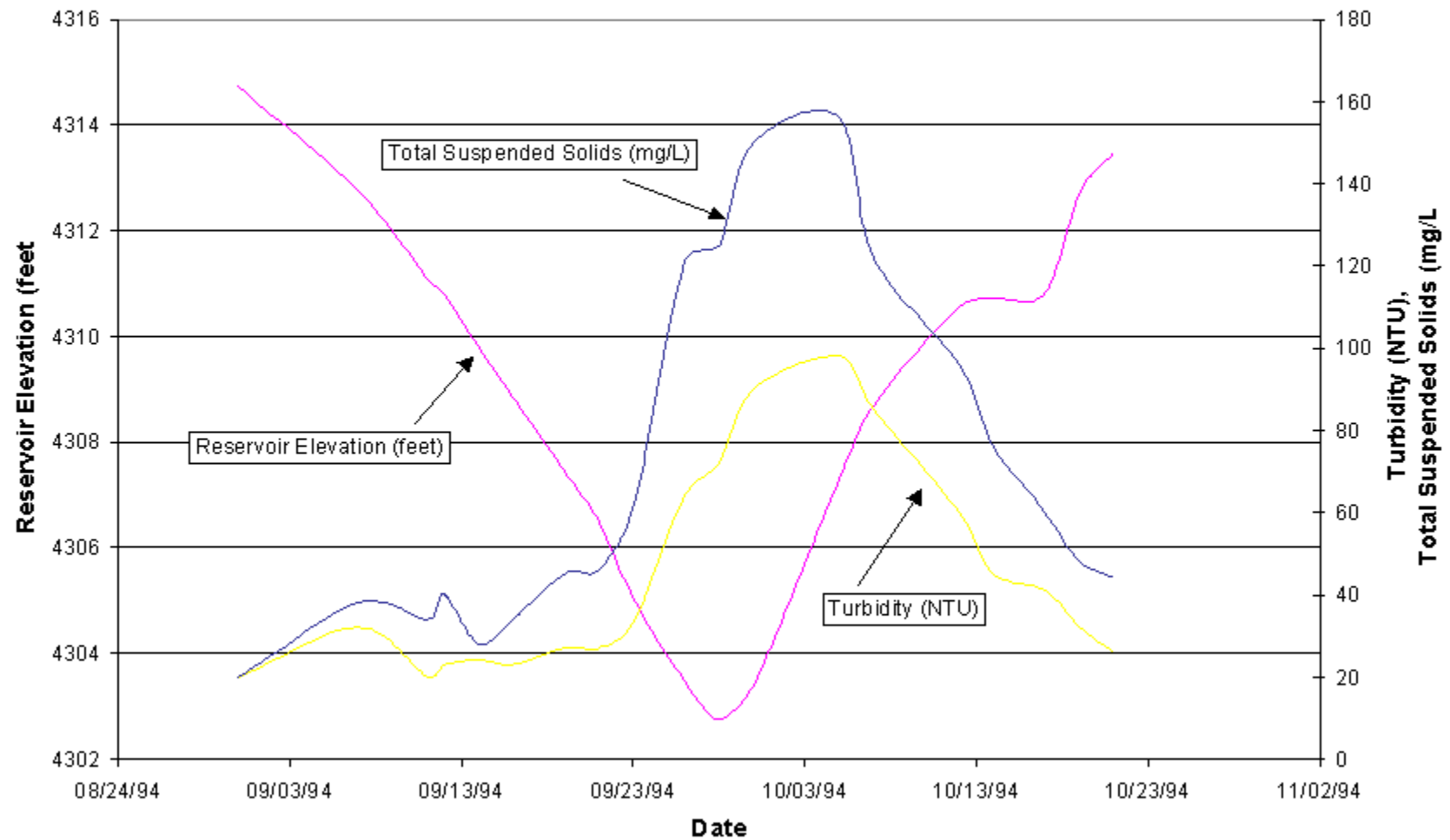
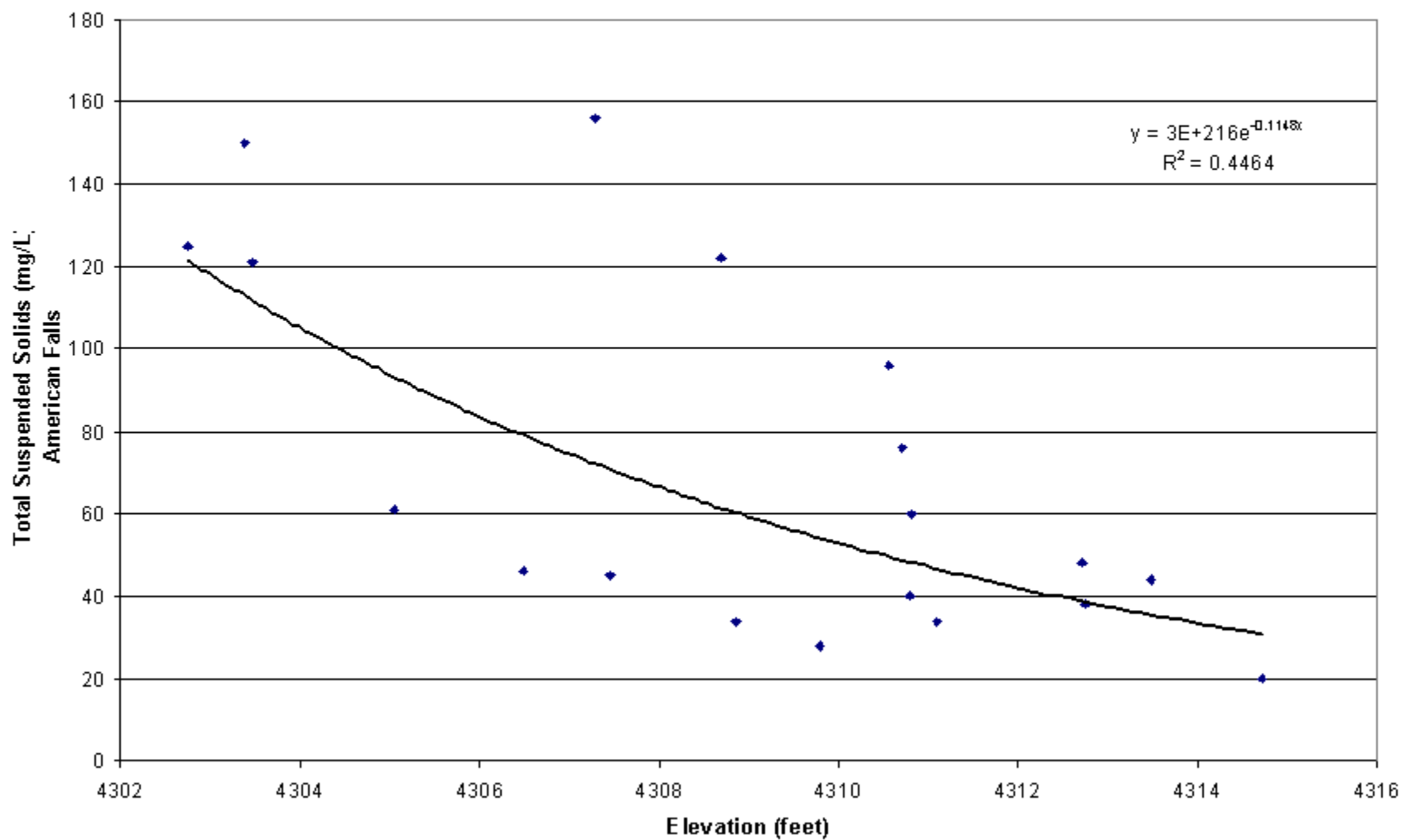
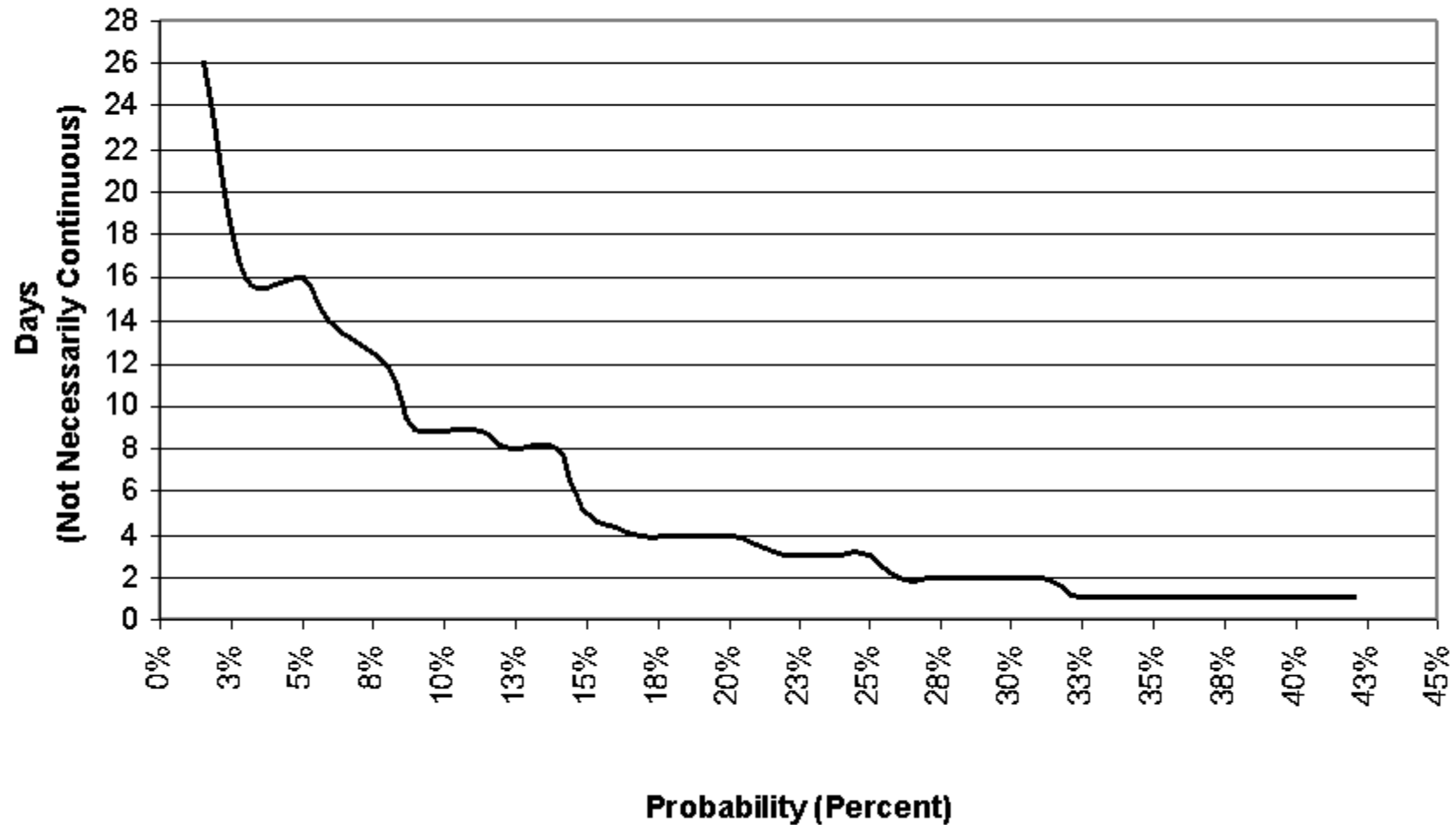


Figure 7

Relationship of Total Suspended Solids versus American Falls Reservoir Elevation 1994



**Figure 8: Probable Number of Days Work Site Would Be Flooded
between October 1 and February 28 for Alternative A**



**Probability of sluice gate use between September 15 and September 30 is negligible.

Preliminary Turbidity and Total Suspended Solids Water Quality Monitoring Program for the Arrowrock Dam Outlet Works Rehabilitation Project

Purpose

The purpose of the proposed water quality monitoring program is to collect turbidity and total suspended solids (TSS) information to describe conditions pre-project, during project construction, and post-project in Arrowrock Reservoir and downstream of Arrowrock Reservoir. The water quality information will assist in developing and analyzing mitigation efforts should unforeseen problems arise with the outlet works rehabilitation project.

Water Quality Studies

Data collection will include sample collection and laboratory analysis. Samples will be collected at three sites and will be coordinated with the activities of the phased valve replacement project to describe turbidity and TSS concentrations before, during, and after construction.

Phase I: Pre -Construction (01/01 - 06/03) - Turbidity and TSS concentrations related to the current operation of Arrowrock Dam and the first two years of the Arrowrock Dam valve replacement.

Parameters to be Collected: Turbidity and TSS data will be collected at each site.

Sampling Locations:

ARR001: Arrowrock Reservoir 500ft above the Dam. Surface and bottom samples will be collected.

BOI031: Headwaters Lucky Peak Reservoir. Surface and bottom samples will be collected

BOI101: Lucky Peak Dam release.

Sampling Frequency: Monthly for one year prior to construction through the first 2 years of construction (January 1, 2001 through June 31, 2003) (30 sampling events).

Phase II: Construction (07/03 - 03/04) - Turbidity and TSS concentrations related to the drawdown of the Arrowrock Dam valve replacement.

Parameters to be Collected: Turbidity and TSS data will be collected at each site.

Sampling Locations:

ARR001, BOI031, and BOI101.

Sampling Frequency¹: Weekly sample collection during drawdown to minimum construction pool and during the construction period (July 1, 2003 - March 1, 2004) (35 sampling events).

Phase III: Post Construction (03/04 - 10/04) - Turbidity and TSS concentrations related to the operation of Arrowrock Dam with the new clamshell gates.

Parameters to be Measured: Turbidity and TSS data will be collected at each site.

Sampling Locations:

ARR001, BOI031, and BOI101.

Sampling Frequency: Monthly from end of construction (March 1, 2004 through October 1, 2004) (7 sampling events).

Reporting

Data will be summarized to describe the turbidity and TSS concentrations related to the operation of Arrowrock Dam before, during, and after construction. The data may be provided to the U.S. Army Corp of Engineers.

¹If the sluice gates are tested for operation or a flood event occurs requiring the sluice gate operation during construction, additional water quality samples may be collected and analyzed to estimate the quantity of sediment flushed from Arrowrock Reservoir. The use of an ISCO-type remote sampler may need to be deployed in the tailwater of Arrowrock Dam for sample collection.